

# Tracking and Data Acquisition Elements Research: Low Noise Receivers: Microwave Maser Development

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*A traveling-wave maser, tunable from 14.3 to 16.3 GHz, has been completed and is ready for installation on the 64-m antenna at Goldstone Deep Space Communication Complex. The maser can provide more than 30 dB net gain at any frequency within its tuning range; an equivalent input noise temperature of 8.5 K has been measured in the laboratory. The maser is a ruby-loaded comb structure (C-axis orientation 90 deg) which operates in a closed-cycle helium refrigerator. The 8000-G magnetic field required for maser operation is supplied by a superconducting magnet. The entire package weight is 70 kg, and the unit is capable of operation in any position.*

## I. Introduction

A traveling-wave maser, tunable from 14.3 to 16.3 GHz, has been completed and is ready for installation on the 64-m antenna at Goldstone DSCC. The maser can provide more than 30 dB net gain at any frequency within its tuning range; an equivalent input noise temperature of 8.5 K has been measured in the laboratory. The maser is a ruby-loaded comb structure (C-axis orientation 90 deg) which operates in a closed-cycle helium refrigerator. The 8000-G magnetic field required for maser operation is supplied by a superconducting magnet. The entire package weight is 70 kg, and the unit is capable of operation in any position.

## II. Maser/Refrigerator Package

The traveling-wave maser/closed cycle refrigerator (TWM/CCR) package is shown in Fig. 1. The assembly (with the pump package cover removed) is much smaller than TWM/CCR packages built previously by JPL (Refs. 1-3). The size reduction is made possible by the use of a superconducting magnet at the 4.5 K station of the refrigerator (see "Superconducting Magnet for a Ku-Band Maser," by R. Berwin, et al., in this issue). The maser and superconducting magnet are contained within the vacuum housing bottom cover (Fig. 1). The refrigerator, with vacuum pump, vapor pressure gauge, and drive

unit showing, is similar to previously used CCRs. The WR 62 signal waveguide input and output connections are located in the upper part of Fig. 1. The overall package height is 87 cm and the package weight is 70 kg.

### III. Pump Package

Two klystrons are used to pump the traveling-wave maser in the push-push mode (Ref. 4). Varian type VA 302 and EM 1138 klystrons each supply 100 mW at 37.35 and 26.45 GHz, respectively, for 15.3-GHz signal frequency operation. The two klystrons with heat sinks, isolators, and a power combining network can be seen in Fig. 1. The pump power combiner uses a low-pass and high-pass filter network (diplexer) so that a minimum of power (less than 1 dB) is lost through the path from the klystrons to the maser pump input connection. Each pair of klystrons can be mechanically tuned to cover maser signal frequency changes of 375 MHz. Electronic tuning of the klystrons permits signal frequency changes of 60 MHz. The entire maser tuning range (14.3 to 16.3 GHz) can be used only by changing klystrons. This limitation is shown by the graph in Fig. 2.

### IV. Signal and Pump Waveguides

Input and output signal waveguides (WR 62) are made of 0.064-cm stainless steel. The WR 28 pump waveguide is 0.025-cm stainless steel. All waveguides are electroplated full length on the inside with 0.00013-cm-thick copper. This combination of stainless steel and copper provides low microwave loss and adequate thermal isolation. The input waveguide is thermally connected to the first stage of refrigeration at a distance of 10 cm from the ambient input flange. Cooling the waveguide reduces noise caused by resistive loss.

Mica vacuum windows manufactured by Airtron (Part #110728) provide hard vacuum seals for the waveguides at the CCR top flange. The low window insertion loss (0.012 dB at 15 GHz) contributes less than 1 deg equivalent input noise to the maser.

Transistions from WR 62 waveguide to 0.218-cm-diam coaxial line are mounted at the 4.5-K station. The maser signal input and output transmission lines are coaxial at 4.5 K.

### V. Maser Slow-wave Structure and Loading

Figure 3 shows the maser structure on the 4.5-K station of the CCR prior to installation of the superconducting magnet. Alumina strips within the maser are used as

dielectric waveguides to transfer pump energy from the pump waveguide at the 4.5-K station to the active maser material.

The maser structure contains two 7.5-cm-long comb type slow-wave structures. Each comb is loaded with ruby (C-axis orientation 90 deg) on one side and an alumina/ferrite isolator on the other side. Yttrium iron garnet pieces ( $0.0035\text{ cm} \times 0.037\text{ cm} \times 0.1\text{ cm}$ ) are cemented to an alumina piece to form the ferrite strip which gives a signal frequency reverse loss (through the maser) of more than 130 dB.

The isolator and ruby orientation permits changes in magnet rotation (away from the optimum 90-deg angle) of  $\pm 0.1$  rad (5.7 deg). This insensitivity to orientation allows assembly of the maser and magnet without a need for magnet rotation when the assembly is cold and operating. Ordinary assembly tolerances provide adequate alignment.

The forward loss and slowing characteristics of the TWM are shown in Fig. 4.

### VI. Performance

A 47-dB net gain, with 17-MHz instantaneous 3-dB bandwidth, was measured at 15.3 GHz. Other measured gain data between 15.25 and 15.64 GHz are shown on Fig. 5. The measurements covered a range which is limited by the mechanical tuning range of the VA 302 pump klystron.

The measured inversion ratio, together with ruby absorption and forward loss data, have been used to calculate the gain and noise temperature available across the maser tuning range. These predicted performance curves are shown in Fig. 5. Noise caused by losses in the vacuum window, waveguide and coaxial transmission line components are included in the predicted equivalent input noise temperature. A measured value of 8.5 K (using a liquid nitrogen cooled load) agrees well with the predicted 8.6 K temperature at 15.3 GHz.

An overall system temperature measurement, using a copper waveguide horn, also demonstrated very low noise capability. The horn was terminated, alternately, by the "cold" sky or by an ambient temperature piece of microwave absorber. The sky was clear; air temperature was 30°C and relative humidity 46%. The total system temperature measured 18.4 K. The receiver following the maser contributed 0.1 K. The system was sufficiently stable to resolve changes in system temperature of 0.1 K.

## References

1. Clauss, R. C., and Quinn, R. B., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network*, Space Programs Summary 37-61, Vol. II, pp. 86-89, Jet Propulsion Laboratory, Pasadena, Calif., January 31, 1970.
2. Clauss, R. C., and Quinn, R. B., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network*, Space Programs Summary 37-58, Vol. II, pp. 50-52, Jet Propulsion Laboratory, Pasadena, Calif., July 31, 1969.
3. Petty, S. M., and Clauss, R. C., "Low Noise Receivers: Microwave Maser Development," in *The Deep Space Network*, Space Programs Summary 37-42, Vol. III, pp. 42-46, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 1966.
4. Clauss, R., "RF Techniques Research: System Studies for Frequencies above S-band for Space Communications," in *Supporting Research and Advanced Development*, SPS 37-61, Vol. III, pp. 90-93, JPL, Pasadena, Calif., Feb. 1970.

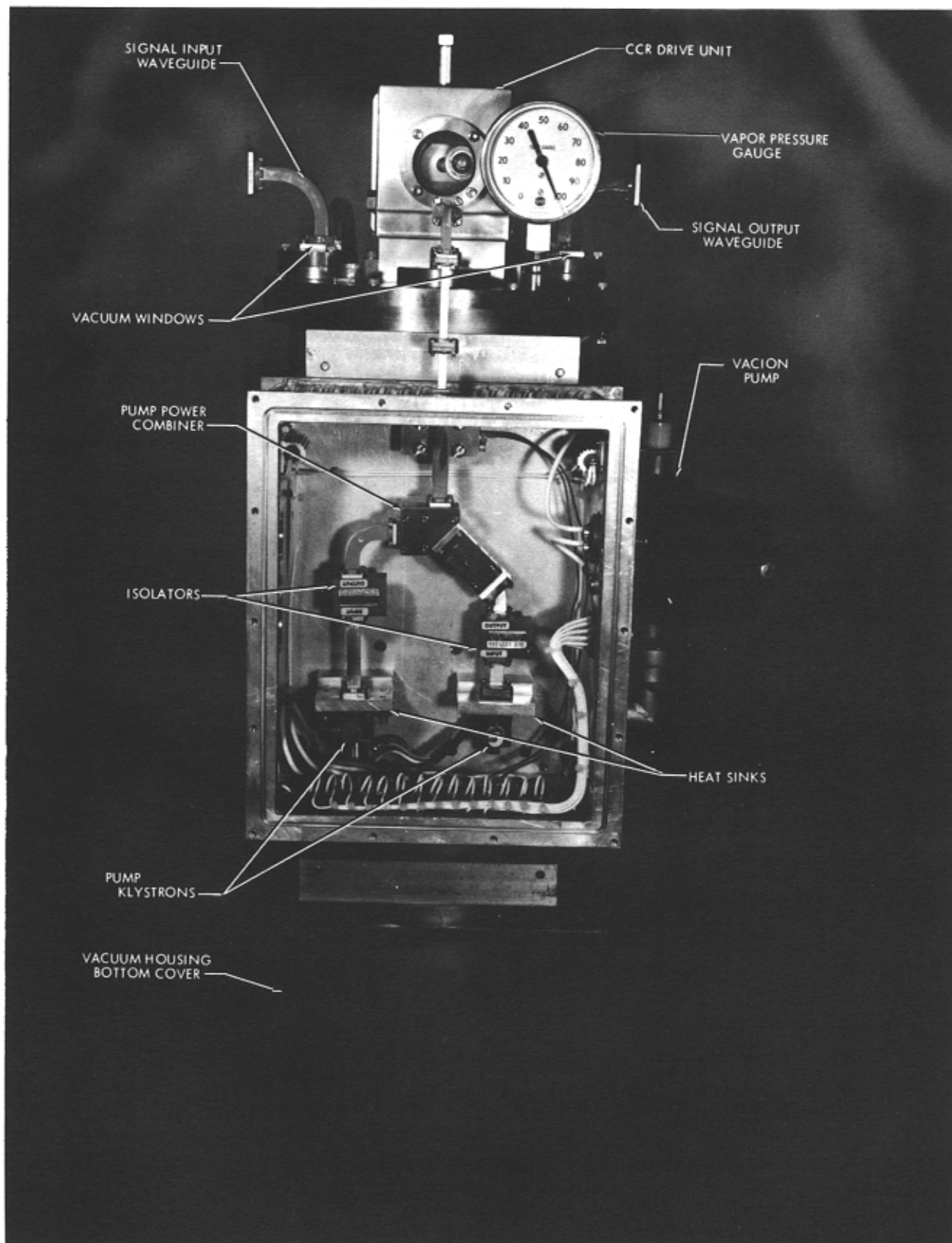
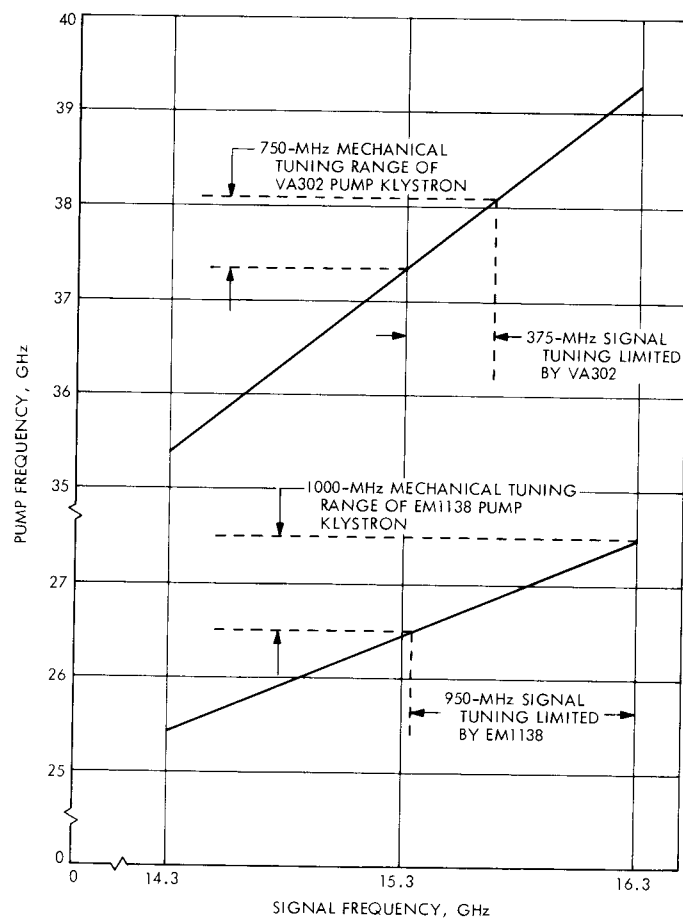


Fig. 1. 15.3-GHz TWM/CCR package



**Fig. 2. Signal and pump frequency tuning**

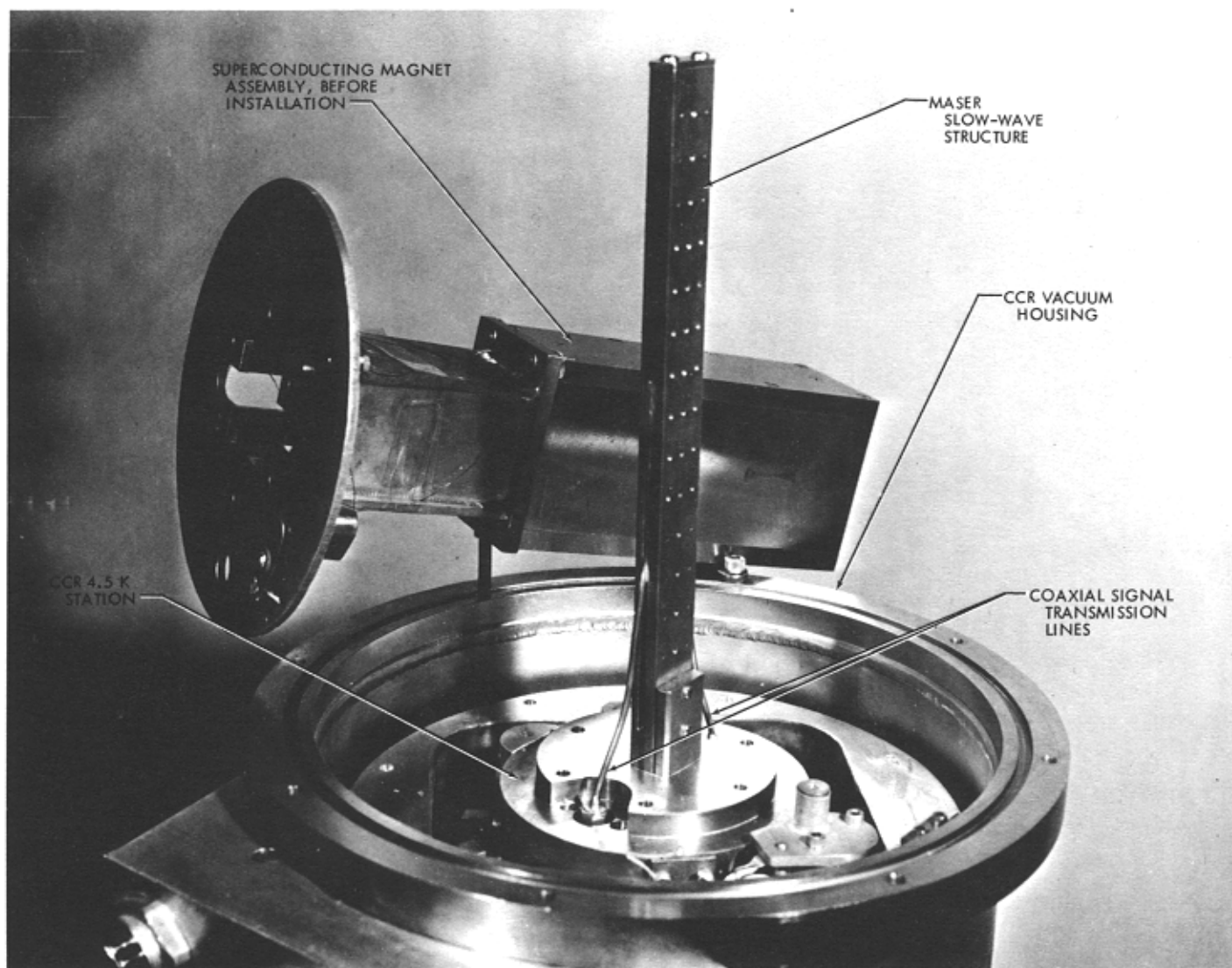


Fig. 3. 15.3-GHz TWM structure

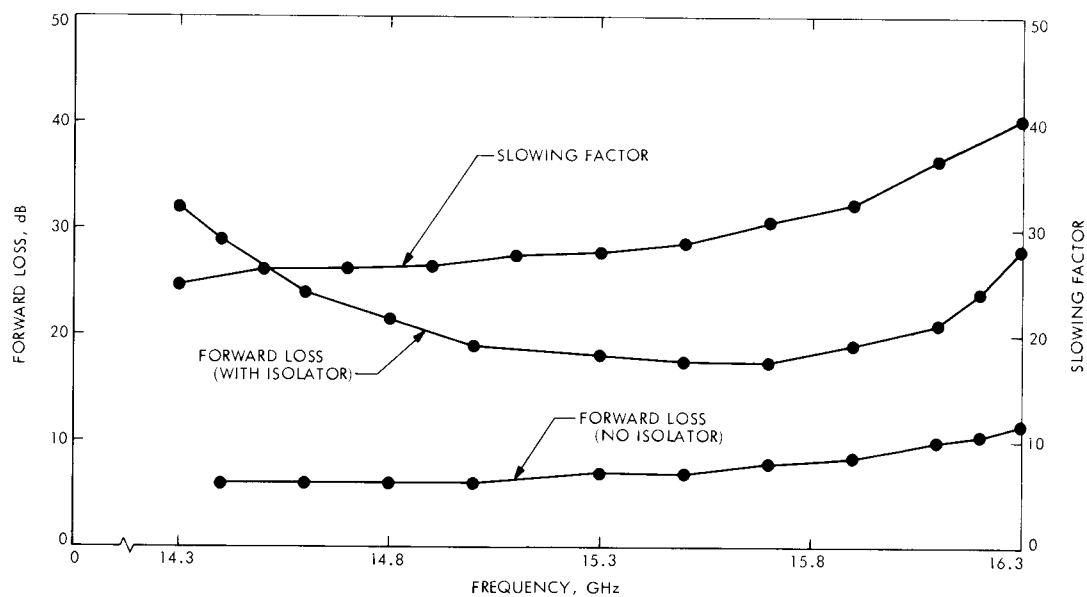


Fig. 4. Slow-wave structure characteristics

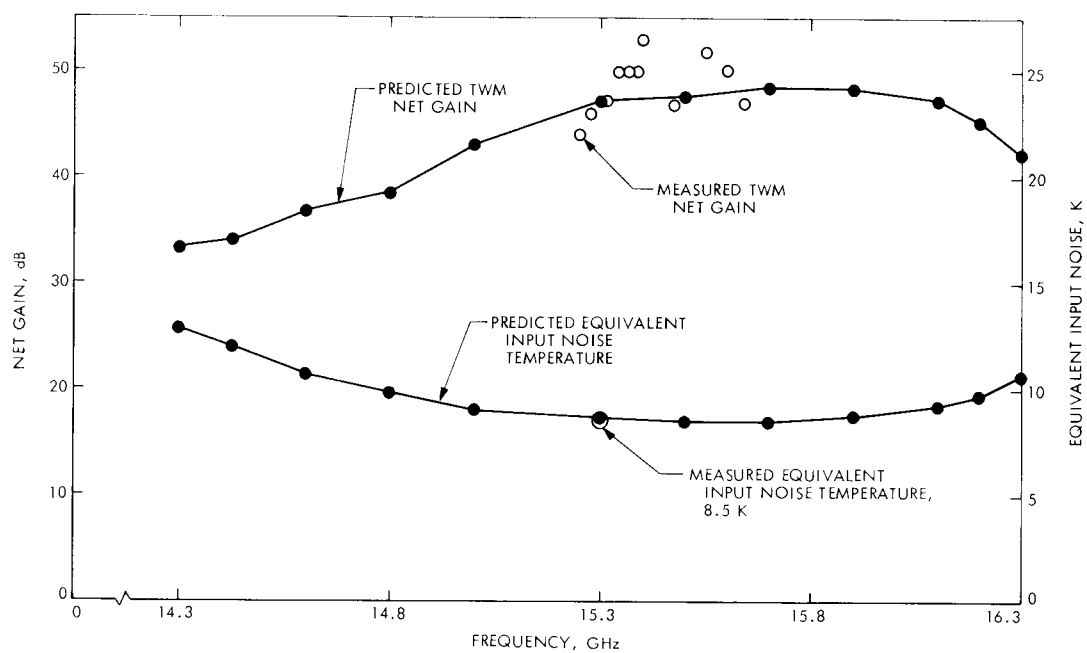


Fig. 5. TWM performance